Human Systems
Integration Division

NTSB Public Hearing
US Airways Flight 1549

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IIFD
Integrated Intelligent Flight Deck

Emergency and Abnormal Situations (EAS) Study

Conducted under NASA's previous Aviation Safety Program (2000-2005)

- Philosophies, Policies, Practices of Dealing with Emergency and Abnormal Situations, Economic and Regulatory Pressures, etc.
- Checklists and Procedures: development, design, types, availability, use
- Aircraft Systems: critical systems, flight protection envelopes, impact and use of automation
- Training: flight crews, cabin crews, ATC, combined training
- Human Performance under High Stress and High Workload
- Crew Coordination and Response to Emergencies and Abnormal Situations
- Roles of Others in Dealing with Emergencies: cabin crew, ATC, dispatch, maintenance, passengers

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ASRS Study [1]

Type of Emergency Incident by How it Was Managed

	Textbook Emergency	Non-textbook Emergency	Totals
Handled Well	19	6	25
Not Handled Well	3	79	82
Totals	22	85	107

"Textbook" Emergency* – situations for which crews have been highly trained, good procedures exist, situations unfold in the same ways as they have been presented during training (*Capt. Richard Fariello, TWA ret.)

"Not Handled Well" – involved a problem with the way in which the flight crew or others responded to the situation and/or with the materials and resources they were to use.

[1] Burian & Barshi (2003). Emergency and Abnormal Situations: A Review of ASRS Reports. http://human-factors.arc.nasa.gov/eas/download/non_EAS/A_Review_of_ASRS_Reports.pdf

Some EAS Findings: Problems with Response

Crew Response:

- Unsure what situation or condition was – ambiguous, incomplete cues
- Never trained for situation or training inadequate/incomplete
- Task saturated, difficulty prioritizing actions and strategic shedding of tasks
- Fixation, tunneling, difficulty with cognitive processing
- Poor communication/coordination
- Unduly influenced by economic, company, personal/professional considerations

Response of Others:

- Lack of understanding of situation/severity (ATC, Cabin Crew, Maintenance, Dispatch)
- Poor communication/coordination

Materials or Resources:

- Checklist not appropriate for situation or didn't exist
- Trouble locating proper checklist and/or proper steps to complete
- Checklist poorly designed, confusing, require multiple jumps within, among, & outside of CL
- Complex calculations required, heavy memory demand
- Checklists very long, critical items appeared late in the checklist

Some "Fixes" - Training

Increase realism of training:

- Procedure doesn't always work
- Present confusing or ambiguous cues
- Not enough time to complete procedure
- Practice shedding tasks, prioritizing, strategic decision making
- Crews should get interrupted by "ATC" and "Cabin Crew"
- Crews are required to put on and use masks and goggles
- Crews are required to make radio calls, complete briefings

Re-think training / scenario philosophy:

- Present scenarios that don't have a clear-cut response or checklist to be used

Increase cross-training, combined training (flight crew, cabin crew, ATC, maintenance, dispatch)

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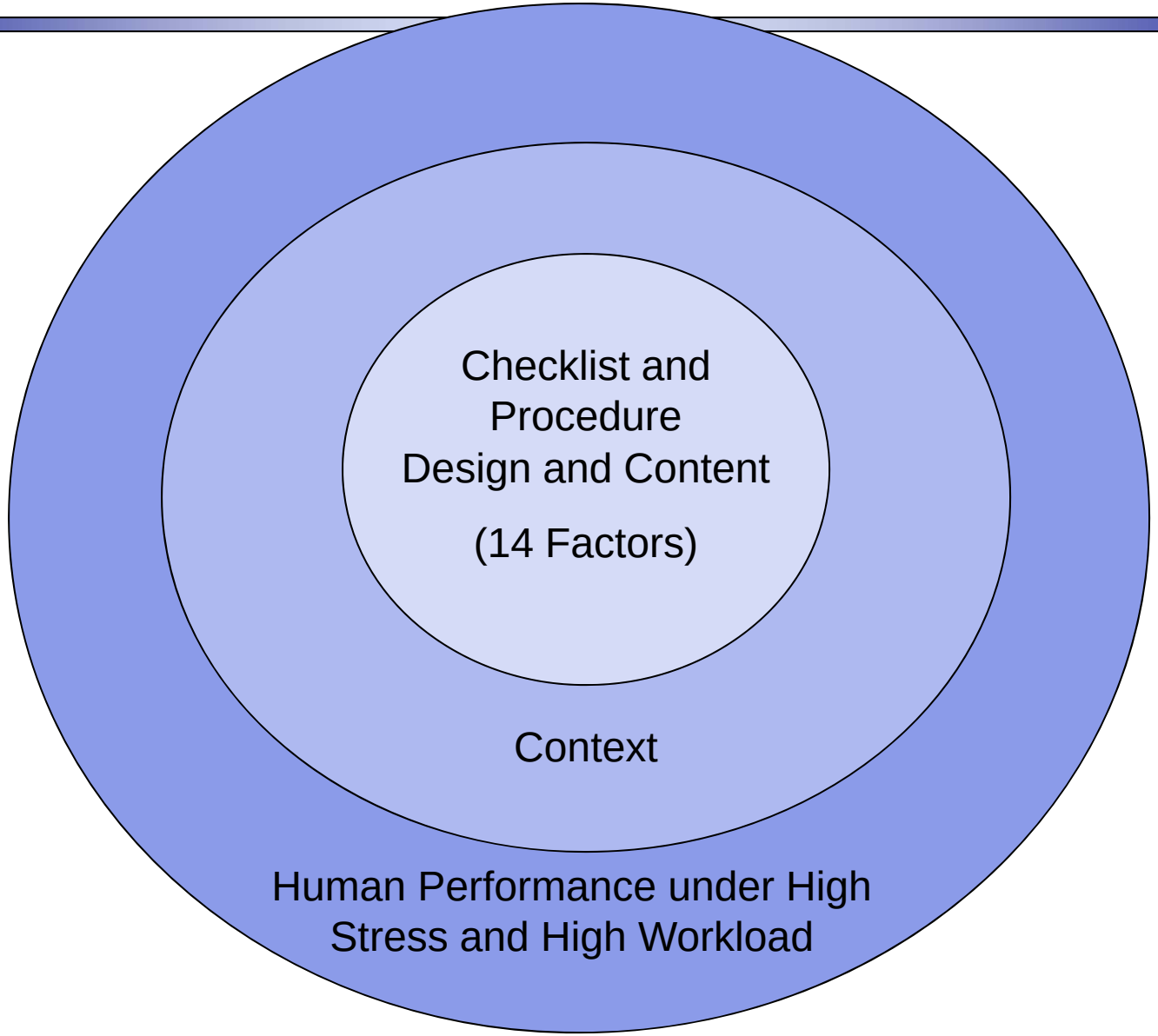
Some "Fixes" – Checklists and Procedures



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Some "Fixes" – Checklists and Procedures

- Improve and support ease of accessing / finding proper checklist
- Design using "Get In – Stay In" philosophy to eliminate jumping
- Consider full range of situations or conditions for which a checklist will be used (levels of severity, when/where situation occurs, weather, terrain, etc.)
- Consider all other operational tasks that must be completed concurrently
- Conduct assessment of workload and timing length of checklists, include all operational tasks
- Build in gates or opt-out points to facilitate evaluating situation or switching focus of tasks (e.g., from dealing with emergency to preparing for landing / ditching)
- Consider location of critical items relative to gates/opt out points
- Consider human performance when under stress and high workload, minimize/eliminate heavy cognitive processing requirements and memory load

Additional Material

Checklist Design and Content Factors
(Paper, Electronic, EFB)

Physical Properties and Interface	-	**size, weight, materials, integration w/displays**
Typography and use of Symbology	-	**font, font size, boldface, intuitive symbology**
Layout, Format, Organization	-	**look, arrangement, philosophy of response**
Purpose	-	**fix, troubleshoot, stabilize/safe, disable/isolate**
Objective (of checklist item)	-	**direct action, inform, assess, make decision**
Length and Workload	-	**physical length, timing length, workload**
Nomenclature & Abbreviations	-	**terms, labels, abbreviations**
Language, Grammar, & Wording	-	**English?, verb tense, reading difficulty, clarity, orientation/perspective, directiveness**
Level of Detail	-	**amount of information provided**
Engineering Completeness	-	**all necessary steps included**
Engineering Coherence	-	**order of steps/timing makes "sense" to aircraft**
Logical Coherence	-	**order of actions makes sense to the pilot and make "sense" operationally**
Checklist Navigation & Jumping	-	**movement within & between checklists/manuals**
Access	-	**finding correct checklist, prime real estate pgs.**

"Purpose" of Checklists and Checklist Items

- Drive the ordering of items within a checklist
- Influenced by situational demands and checklist developer philosophy about proper or desired pilot response
- Purpose Types:
  - Troubleshoot or diagnose the situation
  - Fix – continue functioning back in normal operating mode (e.g. PACK overheat, engine re-light)
  - Stabilize/safe the situation – continue functioning but in degraded or non-normal manner
  - Accommodate the degraded or non-normal functioning of some other system (e.g., different VRef speeds for asymmetrical flaps extended)
  - Isolate, disable, or take off-line – does not continue functioning (e.g., shut down an engine)

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"Access" and Making a Differential Diagnosis

Finding the Correct Checklist:

- Indexes (alphabetical, alphabetical by system, lights, annunciations, quick action, etc.)
- Tables of Content
- Tabs, Section Dividers
- Linked to Caution and Warning Systems – automatic presentation, same titles

Differential Diagnosis:

- Condition Statements (not to be confused with Conditional Items)
- Purpose of Checklist Statements
- Depiction of cockpits lights that should be illuminated
- Description of specific cues to look for (should be ones the crew can actually assess)
- Description of cues that, if present, should point to a different diagnosis
- Notes regarding multiple conditions that present with similar cues or cues that are commonly misleading (e.g., If "Low Oil Pressure" look first to see if engine is running)

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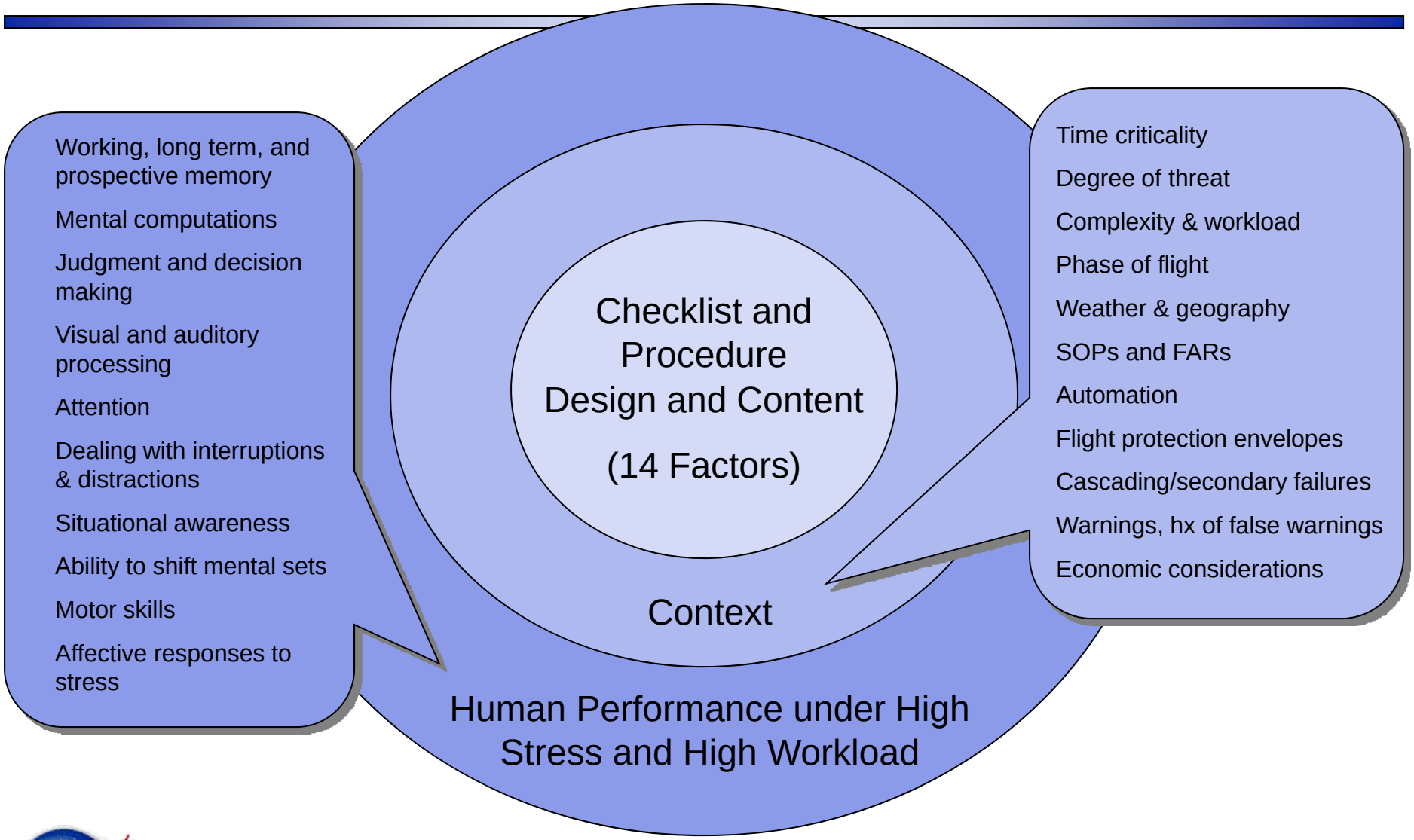
Time Critical Emergencies and Common Characteristics of Human Performance

- Initial shock / surprise
- Difficulty diagnosing the situation because:
  - Cues are ambiguous, misleading, confusing, opaque
  - Incomplete information, information comes in piecemeal
  - Reduced cognitive processing capabilities
  - Lack of time to adequately process information/cues or gather more information
- If novel or unpracticed situation, may be unsure of correct action
- Motor skills are relatively robust under high stress and high workload
- Cognitive capabilities are affected by high stress and high workload:
  - Working memory - capacity and amount of time information held is reduced
  - Tunneling or fixation
  - Difficulty in choosing / assessing options, planning, decision making
  - Shedding tasks – sometimes strategic, sometimes tasks just dropped, missed
- When task saturated tend to revert to reactive mode rather than be strategic, proactive, planning

Some "Fixes" – Checklists and Procedures



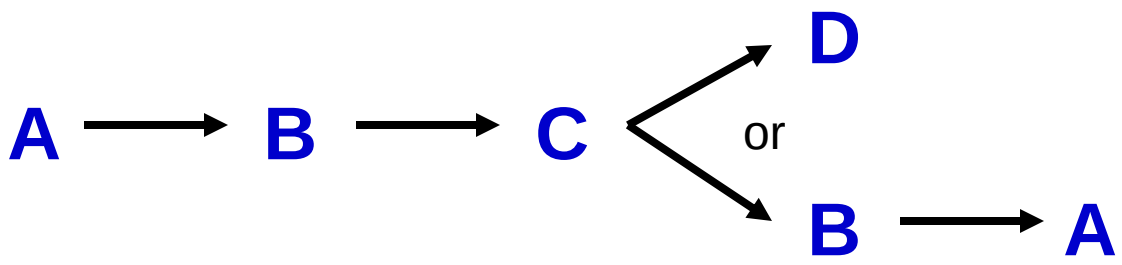
Checklists and Procedures: Context and Human Performance Considerations

Some Findings from the Research

Checklists and Procedures: Context and Human Performance Considerations

Multiple Jumps Among Emergency/Abnormal Checklists

A complicated jumping chain found in **10 out of 11** B737 QRHs examined:



A – Loss of Thrust on Both Engines

B – Inflight Engine Start

C – Engine Failure Shutdown

D – One Engine Inoperative Landing

Checklists and Procedures: Context and Human Performance Considerations

Pilots routinely make errors in correctly recalling "memory items"

Air Carrier/Manuf.	*N* of CL with MI	Total *N* of MI	Action Item MI	Conditional MI	Note MI	Other MI
A Classic B737	23	120	93	21	3	3
B Classic	4	15	13	1	0	1
C Classic	16	112	73	16	21	2
D Classic	5	17	15	2	0	0
Boeing Classic	**16**	**113**	**73**	**16**	**22**	**2**
E NG B737	9	20	17	3	0	0
F NG	3	11	10	1	0	0
G NG	12	45	37	5	2	1
H NG	10	44	35	5	2	2
Boeing NG	**18**	**129**	**83**	**19**	**24**	**3**
Boeing NG – Rev.*	**13**	**77**	**52**	**10**	**14**	**1**

* Phase 1 revisions

Checklists and Procedures: Context and Human Performance Considerations

Number of Memory Items in Selected Checklists

Checklist Title	Number of Items in Each Checklist										
	B737 Classic					B737 Next Generation					
	A	B	C	D	Boeing	E	F	G	H	Boeing	Boeing-R*
Aborted Engine Start	13	0	15	2	15	4	0	7	5	15	1
Eng. Fire, Svr Dmg, Sep	8	0	13	0	13	0	0	2	0	13	13
Loss Thrust Both Eng.	-	4	4	0	4	0	0	4	6	4	4
Rapid Depressurization	11	3	12	2	12	2	2	2	4	11	12
Emergency Descent	9		12		12	0	0	0	0	12	12
Runaway Stabilizer	7	0	8	2	8	4	0	0	6	8	8
Uncommand. Rudder	8	7	7	9	7	1	7	8	7	7	7
Uncommand. Yaw / Roll	9		7		7	1		8		7	

* Phase 1 revisions

Checklists and Procedures: Context and Human Performance Considerations

Applying multipliers to landing distances – working memory load

LDG CONF – APPR SPD – LDG DIST CORRECTIONS FOR FAILURES		FLAPS LEVER POSITION FOR LDG	APPR SPD : INCREMENT TO V_{REF}	LDG DIST CONF FULL MULTIPLY BY
ELEC	EMER ELEC CONFIG	3	10	1.7
	DC EMER CONFIG	NORM	–	1.7
	DC BUS 1 + 2	NORM	–	1.55
	DC BUS 2	NORM	–	1.3
	DC ESS BUS / AC BUS 1	NORM	–	1.1
FTL CTL	ALTN LAW/DIRECT LAW ELAC 1 + 2/L(R) ELEV FAULT STAB JAM/L + R ELEV FAULT	3	10	1.2 *
	ONE SPLR FAULT (except n°5)	NORM	–	1.1
	TWO SPLR FAULT	NORM	–	1.1
	Three or more SPLR FAULT	NORM	–	1.15
	SEC 1 or 3 FAULT	NORM	–	1.1
	SEC 2 FAULT	NORM	–	Negl.
	Two SEC FAULT	NORM	–	1.3
	SEC 1 + 2 + 3 FAULT	3	10	1.5
FLAPS/ SLATS	FLAPS and SLATS at zero	1	60 (APPR) 50 (THRESHOLD)	1.8 *
	0 < FLAPS < 1 : Slats < 1	3	45	1.8 *
	Slats ⩾ 1	3	25	1.3 *
	1 ⩽ FLAPS < 2 : Slats < 1	3	30	1.4 *
	Slats ⩾ 1	3	15	1.2 *
	2 ⩽ FLAPS < 3 : Slats < 1	3	25	1.35 *
	Slats ⩾ 1	3	10	1.15 *
	FLAPS = 3 : Slats < 1	3	25	1.35 *
	1 ⩽ Slats ⩽ 3	3	10	1.15 *
	Slats > 3	3	5	1.1 *
	FLAPS > 3 : Slats < 1	Not allowed		
	1 ⩽ Slats ⩽ 3	FULL	10	1.15 *
	Slats > 3	FULL	5	1.1 *

1.7

1.55

1.8

1.35

1.15

Burian – NTSB Hearing, June 9, 2009
US Airways 1549

Complex Navigation

Start

[redacted] | ABNORM 1-2
Sep 09/02

1. SINGLE ENGINE PROCEDURES

In-Flight Engine Shutdown

Accomplish an engine shutdown only when flight conditions permit:

(1) Affected thrust lever ..... CONFIRM AND IDLE
(2) Affected thrust lever ..... CONFIRM AND SHUT OFF
(3) Affected HYDRAULIC pump ..... ON
- If left engine shut down .... HYDRAULIC 1 ON
- If right engine shut down ... HYDRAULIC 2 ON

(4) Affected FUEL, BOOST PUMP ..... CONFIRM AND OFF
(5) WING A / I CROSS BLEED ..... SELECT NON-AFFECTED SIDE
(6) LH or RH COWL ANTI-ICE ..... AFFECTED SIDE OFF

▼

QUICK REFERENCE HANDBOOK CSP C-022 | POWER PLANT MALFUNCTIONS

[redacted] | ABNORM 1-3
Sep 09/02

Enroute terrain clearance is a consideration:

Yes
(7) Operating engine thrust lever ..... SET TO CLIMB
(8) Airspeed ..... MAINTAIN ENROUTE CLIMB SPEED
(9) Allow the airplane to climb or descend to the single engine level-off altitude.

(10) APU (if available) (37,000 feet and below) ..... START

NOTE
Do not attempt to relight an engine that is suspected to be damaged (engine fire, rotor burst, reverser deployed, etc...).

Engine damage is suspected/intentional shutdown:

Yes
(11) Land at the nearest suitable airport.
(12) Single Engine Approach and Landing Procedure ..... ACCOMPLISH (Refer to ABNORM 1-9)

- END -

No
(11) Engine Relight procedure .. ACCOMPLISH, as required
- Starter-Assisted Cross Bleed Relight Procedure (Refer to ABNORM 1-3)
- Starter-Assisted APU Bleed Relight Procedure (Refer to ABNORM 1-5)
- Windmilling Relight (Refer to ABNORM 1-7)

Relight engine using starter-assisted start whenever possible.

---------- END ----------

No
(7) Proceed to step (10)

ENGINE RELIGHT PROCEDURE

Starter-Assisted Cross Bleed Relight

(1) Altitude ..... 21,000 FEET AND BELOW
(2) L and R FUEL, BOOST PUMP ..... CONFIRM ON
(3) BLEED SOURCE ..... OPERATIVE ENGINE
(4) ISOL ..... OPEN

▼

QUICK REFERENCE HANDBOOK CSP C-022 | POWER PLANT MALFUNCTIONS

Checklists and Procedures: Context and Human Performance Considerations

Crew confusion – FedEx 1406, September 5, 1996[1]

FE was confused by step 5 and did not complete steps 6 and 7

Items Pertaining to Adjusting Cabin Altitude or Flight Level

4.	**Airplane Altitude**	CAPTAIN'S DISCRETION
	A. Land as soon as possible.	
or		
	B. If above FL 270, consider descent to FL 270. Manually raise cabin altitude to 25,000 ft.	
or		
	C. If below FL 270, and an immediate landing is not possible, climb to FL 270. Manually raise cabin altitude to 25,000 ft. using the MANUAL CAB ALT control wheel.	
5.	**If unable To Extinguish Fire/Smoke**	MANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET
6.	**Cabin Air Shutoff T-Handle**	PULL
7.	**Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.**	

[1] National Transportation Safety Board (1998). *Aircraft accident report: In-flight fire/emergency landing.* AAR-98/03. Washington, DC: National Transportation Safety Board.

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http://human-factors.arc.nasa.gov/eas

Flight Cognition Laboratory

http://human-factors.arc.nasa.gov/ihs/flightcognition/

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